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Lamps and Their Uses

By J. N. ALDINGTON, B.Sc., Ph.D. *(Fellow)*

Summary

The design of a light source cannot be separated from its use. Increasingly in recent years has this fact influenced lamp development and research. Some of the factors of which account has to be taken in the evolution of new sources are mentioned. It is considered that the remarkably active phase of invention in the associated fields of metal vapour discharge lamps and fluorescent lamps is now merging into a period of consolidation characterised by the continuous improvement of existing types.

Following the basic classification used in the light source reports to the 1948 and 1951 Plenary Sessions of the C.I.E., certain special features of lamps for each group are described to illustrate their relation to user requirements. Mention is made of the special problems which arise in determining the optimum colour for fluorescent lamps for different uses.

(1) Introduction

The past 25 years have witnessed greater technological advances in the lighting industry than any comparable period since man first harnessed the flickering flame of the pine-wood faggot to light his way. The present paper contends that developments in light sources have in many instances outstripped developments in their application. There is evidence also that the peculiarly fertile period of the last two decades in lamp development is now merging into a period of consolidation. The primary forces which influenced lamp research in the exciting years following development of mains voltage metal discharge lamps in about 1930, arose from the engineering aspects of the lamps themselves. To-day, however, it is already evident that user requirements interpreted by lighting engineers are exercising an increasing influence. This is a good thing for the lamp cannot be separated from its use. Nevertheless there are definite features in every light source which stem from the fundamental physical and chemical requirements of the materials from which the source is constructed. Some of these are examined in the present paper; the inter-relation between certain features of lamp design and the optimum use are also considered.

(2) Characteristics of Radiant Energy

Whatever the nature of a source of light the emitted radiation at any chosen wavelength is identical with that from any other source. This is only true however if we consider a particular wavelength in the radiation spectrum and not the spectrum as a whole. In most lamps the spectral characteristics of the visible light, together with the associated radiation in the ultra-violet and infra-red regions, carries unmistakable birthmarks. While, therefore, any particular frequency of radiant energy has no properties which indicate its origin, the complete spectrum from a single source is generally sufficiently characteristic for the source to be recognisable. It was this fact which constituted one of the major challenges to research workers in the field of light production, for one of the objectives in the production of luminous flux is to discover means for erasing these birthmarks and controlling the characteristics and distribution of radiant energy within the visible spectrum. The way in which this control has been effected in the design of certain metal vapour and fluorescent lamps will be discussed in later sections of this paper. No appreciable control of tungsten filament lamps is possible except by using them in conjunction with other types of light source. This is not only practical to-day, both with metal vapour discharges and fluorescent lamps, but it has led to developments of considerable interest to the user.

Dr. Aldington is with Siemens Electric Lamps and Supplies, Limited. The manuscript of this paper was first received on March 20, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 19, 1954.

(3) Some Methods for Producing Light

Many well-known phenomena cause the emission of light. Practically always the light is produced as the by-product of some physical or chemical change and generally it is accompanied by other radiation invisible to man. Most of the methods for producing light can be grouped under one or other of the following divisions: Incandescence; electron or ion bombardment; discharges through gases; discharges through metallic vapours; fluorescence; field excitation; chemical glows and flames.

Notwithstanding the wide range of phenomena covered by the above table, there is a fundamental similarity deriving from the constitution of matter itself, for the production of light always arises from disturbances within the atoms or molecules comprising the source of light. Within any one of the above divisions there are several ways in which these disturbances can be stimulated. In general, however, of the several possibilities one method is found to offer material advantages over the others and has hence become the preferred method for use in practical lamps. This fact can be illustrated by taking two examples, one from the incandescent division and the other from the fluorescent.

A piece of tungsten rod can be raised to incandescence by any of the following means :—

(a) by heating it in a high temperature flame,
(b) by passing through it an electric current of sufficient strength,
(c) by subjecting it to electron or ion bombardment,
(d) by rapidly oxidising it with sodium nitrite.

For a variety of reasons, some of which will be mentioned in the next section of the paper, the preferred method for raising the tungsten rod to incandescence is that given in (b). It is interesting however to note that method (c) has been used for many years in "Pointolite" lamps. An important fact to remember is that whichever of the four methods is used the quality of the radiation is a function only of the temperature attained by the rod and is independent of the method of heating employed.

A somewhat similar state of affairs prevails when light is produced by fluorescence. There are many ways of exciting fluorescence in suitable phosphors, but they may be broadly classified under two headings :—

(a) excitation by photons of radiation
(b) excitation by particles.

Dealing first with method (a), it has been found that a surprisingly large range of frequencies of exciting energy will cause the emission of light from a given phosphor. Whatever the frequency of the incident energy however, the emitted light will be characteristic of the phosphor and not of the radiation which is used to stimulate it. For example, if we consider the excitation of a selected phosphor by photons, the energy may vary from visible radiation itself through the ultra-violet to X-rays and gamma-rays; whatever the form of energy, after absorption some will be re-emitted as visible light characteristic of the phosphor itself.

Similarly with method (b) the particles may be electrons, ions, alpha-particles or other corpuscular radiations of the same general character, but here again when the phosphor crystal is excited the resultant light is characteristic of the crystal and not in general of the energy which is absorbed.

As far as practical lamps are concerned the most important means of phosphor excitation is by ultra-violet radiation.

(4) The Evolution of Practical Light Sources

In the preceding section some of the basic methods by which light is produced have been considered.

In practice most existing lamps have evolved by a process of gradual change from earlier types which themselves were developed largely empirically but which often

bore the hall-mark of almost prophetic design. A study of the large number of patents on early lamps illustrates this point and indicates how the method of trial and error was applied in this as in almost all other fields of invention. To-day, however, largely as a result of the growth of accurate scientific knowledge, it is possible to survey theoretically in some detail the possibilities which are known to exist and to select the most promising line of enquiry before practical development is attempted. To give a very simple example, in considering *de novo* an incandescent light source, and assuming equal efficiencies for two different primary sources of energy, it would obviously be more efficient to heat a metal by passing an electric current through it than by heating it with a flame as some at least of the energy in the flame would never reach the metal at all. The incandescent gas mantle is a most elegant solution to this type of problem. The mantle, as the name implies, is so shaped in relation to the gas burner with which it is to be employed as to conform to the maximum temperature zones of the flame; it is thereby enabled to collect a very high percentage of the input energy from the combustion of coal gas in air. The ultimate efficiency of the gas mantle, however, results not only from the effective thermal design but also from the selective radiation properties of the particular combination of rare earth oxides employed in the mantle fabric.

It is self evident that a light source dependent upon the consumption by oxidation of some of the elements in the lamp can only have a short life. For example, the electrodes in the carbon arc may, before adjustment or replacement is necessary, burn for only a matter of minutes or at the most for an hour or two. Similarly in the chemical example I mentioned in which the oxidation of tungsten by sodium nitrite produced light, the life of the tungsten rod would be a few minutes only before it was totally consumed.

The life of a tungsten rod or other refractory metal raised to incandescence by electron or ion bombardment could be made quite long, but analysis of the energy transfers involved in the process suggest a low efficiency and the complexity of the arrangements would in the aggregate cause the rejection of this method for general purpose lamps. Of the methods considered therefore, only that in which the metallic conductor is heated by the passage of an electric current remains and it is this method which is the basis of all incandescent light sources. For reasons which are now well known, over the whole period of 60 or more years in the history of the incandescent lamp, the conducting member has been in the form of a thin wire either straight or coiled and supported inside a hollow glass bulb exhausted of air or filled with some gas chemically inert to the filament material.

The preferred method for the excitation of inorganic phosphors in the fluorescent lamp resulted from somewhat similar considerations. It had been known for many years that phosphors were excited by X-rays. Indeed, the discovery of X-rays is said to have depended on this phenomenon. Similarly, it was known that particle bombardment—by electrons for example—could excite fluorescence in inorganic phosphors. Neither of these methods has, however, so far led to a practical light source, although some most interesting results can be obtained in the laboratory. The principal difficulty arises from the relative complication of the means for producing the bombarding radiation or particles.

It was only when phosphors were developed which could be excited very efficiently by the resonance radiation from the low-pressure mercury vapour arc that a really practical fluorescent lamp was evolved. It is now believed that of all possible methods of exciting fluorescence in inorganic phosphors, that of exposure to the ultra-violet radiation from mercury is by far the most efficient. Consequently, the problems which had to be solved in the development of the modern fluorescent lamp were largely engineering problems stemming from the need to associate the fluorescent powder in the most efficient manner with a discharge producing the maximum proportion of

the active ultra-violet radiation. The nature of these problems and the solutions which were found have been fully documented in the Transactions of this Society and elsewhere.

The third main class of electric lamp is that known as the electric discharge lamp. Dealing first with the mercury vapour lamp, a phenomenon which has been exploited with great success is the effect of vapour pressure on the electrical and luminous properties of the discharge. The luminous column from an electric discharge through mercury vapour increases in brightness as the vapour pressure is increased. At the same time the voltage gradient in the discharge increases and, with existing materials for the envelope and electrodes, gradients as high as 500 volts per cm. have been used in practical discharge lamps. Such values should be compared with gradients of less than 1 volt per cm. in the discharge column of the Cooper-Hewitt lamp.

The use of higher mercury vapour pressures not only increases the efficiency of the electrical circuit and the compactness and brightness of the light source, but also improves the attainable efficiency. It soon became evident, for example, that high-pressure mercury vapour lamps consuming only about 100 watts could be made with initial efficiencies as high as 40 lm./w. With proper control of most of the factors influencing efficiency, experimental values as high as 70 lm./w. have been obtained with special higher-powered mercury lamps.

In the general investigations of the last twenty of thirty years it was found that other elements of high atomic complexity behaved in a not dissimilar manner to mercury vapour, and use has been made of this fact in the design of krypton- and xenon-filled light sources of a variety of forms to some of which further reference will be made.

During the period under review research engineers interested in light-source developments have naturally examined many other methods for producing light. One such method which has received perhaps wider publicity than is justified by its practical potentialities is that of electro-luminescence. For this, use is made of a phenomenon by which certain phosphors can be caused to emit light when subject to an alternating electrical stress. So far, however, the indications are that while the physical make-up of an electro-luminescent source can be relatively simple, the production of the optimum field conditions in respect to both voltage and frequency leaves something to be desired from the point of view of simplicity. As a result, the overall efficiencies of the known electro-luminescent sources fall far short of that of other light sources of comparable consumption. The same is largely true of other phenomena capable of producing light which have been examined. For example, it is possible to produce interesting luminous effects from exhausted glass spheres containing suitable phosphors, but such devices are more laboratory curiosities than forerunners of new and practical lamps.

In the author's considered opinion it is unlikely that there will be dramatic increases in the efficiency of light production from existing types of lamp. The lamp industry of the world is entering upon a phase of slow but steady evolution not only of the older sources but of the relatively new sources which have resulted from the intensive developments of the past two decades.

(5) Some Factors of Lamp Design

An understanding of some of the basic principles underlying the design of lamps is desirable—and often is essential if the best type of lamp is to be chosen for a particular use. The dimensions and characteristics of the large range of lamps now available in each class—incandescent, fluorescent and discharge—are readily obtainable from the literature and will not be given here. The present section is devoted to a discussion of selected features likely to be of interest to the user.

(5.1) Tungsten Filament Lamps

Notwithstanding the remarkable developments in the field of electric discharge lamps and fluorescent lamps it is believed that the tungsten filament lamp in its many and varied forms and with its wide flexibility of design, voltage range, and light output is the best source of light for a host of uses, in most of which discharge lamps and fluorescent lamps cannot even rank as competitors.

(5.2) Low-voltage Types

(5.2.1) *Some General Considerations*

Originally low-voltage lamps were probably designed to operate from small sources of supply such as primary cells, lead or alkaline accumulators or low-voltage generators. The voltage of the supply and the desired light output largely governed the size and shape of the filament, as only an inch or two of tungsten wire for each 10 volts was necessary to give the required voltage drop in the lamp. From the earliest days of the drawn-wire lamp it was realised that a simple coil was the easiest geometrical form for the filament, and this type of filament is used in practically all low-voltage lamps to-day.

Later it was realised that the low-voltage lamp, with its short, stout filament, could be accurately positioned in relation to a reflecting or refracting optical system, or a combination of both, and this lent itself to efficient light control. Another feature of the low-voltage lamp which commends it for many purposes is the robustness of its short thick filament resulting in the ability to withstand reasonable shocks without damage. In Table 1 the dimensions of the filament wire in two low-voltage lamps and two relatively high-voltage lamps are compared. The 6- and 12-volt 36-watt headlamp filaments are compared with the 110- and 220-volt 40-watt filaments of the G.L.S. lamps. While there are differences in designed life and a slight difference in wattage these do not vitiate the general comparison.

Table 1

Volts	Watts	Lamp Type	Filament Wire Dimensions	
			Length	Diameter
			mm.	mm.
6	36	Autohead Lamp	43	0.21
12	36	,, ,,	81	0.143
110	40	General Lighting Service	403	0.0366
220	40	,, ,, ,,	653	0.0227

There is a further point of material interest in comparing low- and high-voltage lamps of the same wattage. The lower the designed voltage, and therefore the greater the filament wire diameter, the higher becomes the efficiency of the lamp assuming the life has been fixed. This generalisation is true until quite low voltages are reached, at which stage end cooling effects predominate and the filament temperature increases steadily from each end towards the centre. In low-voltage lamps, therefore, at the end of life the filament will normally be found to have failed in its centre turns as these turns will have been the hottest during life.

With lamps designed for voltages not exceeding about 15, the filament in general requires no support except for its end connections. A very simple construction is therefore possible and the number of filament configurations which can be used is interesting, as within fairly wide limits the filament can be adapted to give optimum results in any desired optical system. Fig. 1 shows a variety of standard filament shapes for low-voltage lamps.

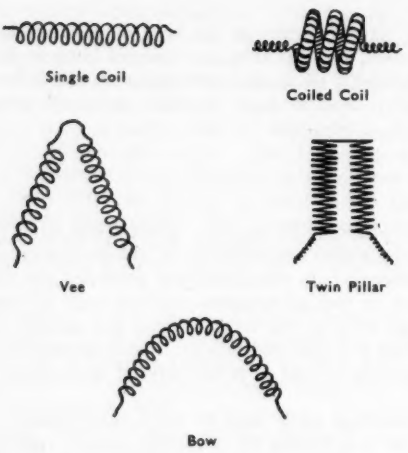

Fig. 1. Filament shapes.

(5.2.2) *Line Filament*

Lamps with short stiff coiled filaments are available for many purposes. One of the most interesting examples is the double filament prefocus bulb used in the modern motor car headlamp. The dipped beam is produced by switching from a centre mounted filament to an offset filament and the positioning of the two filaments in relation to the optical axis of the reflector and refractor system of the headlamp governs not only the production of a flat top beam of narrow vertical spread and wide horizontal spread but it also determines the displacement of the beam to the horizontal and vertical axes. Fig. 2 shows an end view of one of these prefocus headlamps while Fig. 3 shows the beam patterns produced by the complete headlamp assembly. The production of lamps with high precision mounting of one, two or more filament coils in respect to each other and to an accurately prefocussed lamp cap is one of the important developments of recent years.

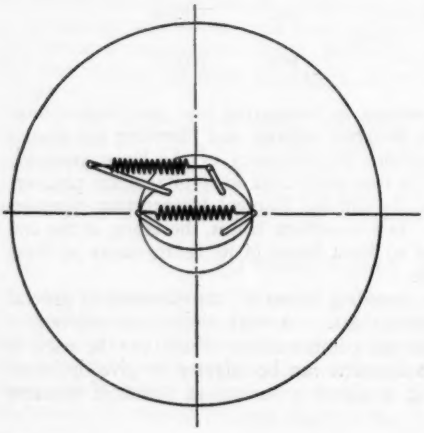

Fig. 2. End view of British pre-focus headlamp.

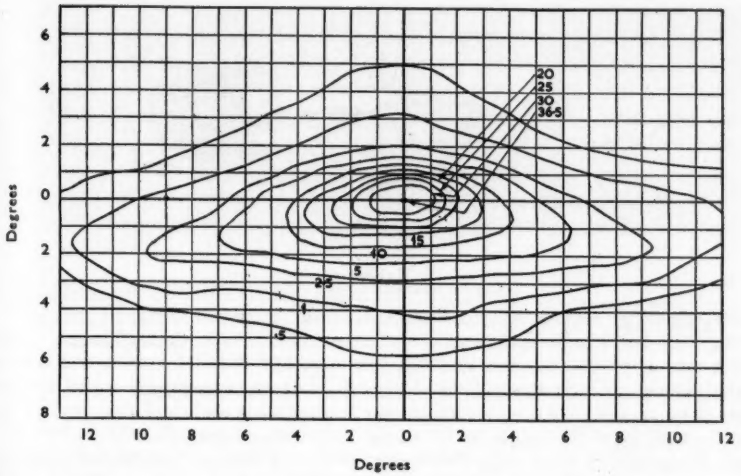

Fig. 3 (a). Beam pattern of headlamp. (12-volt 42/36-watt bulb. Measured at 12·5 volts giving 787 lumens, nominal output at 12·8 volts. Figures are in thousands of candelas.)

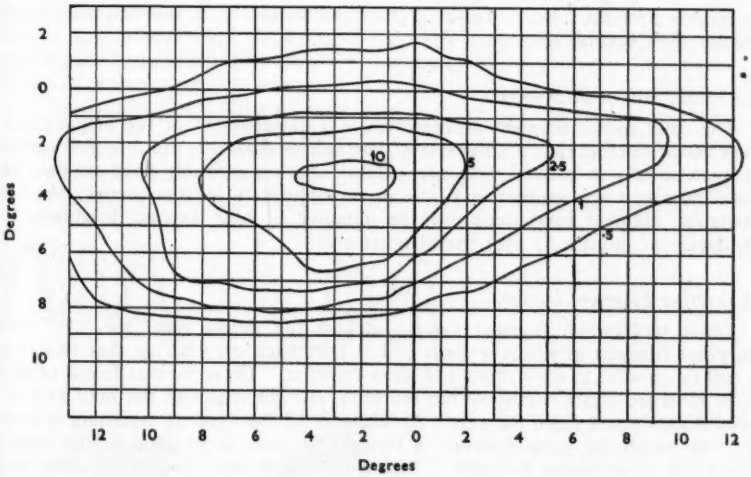

Fig. 3 (b). Beam pattern of headlamp. (12-volt 42/36-watt bulb. Measured at 12·6 volts giving 630 lumens, nominal output at 12·8 volts. Figures are in thousands of candelas.)

(Figs. 3 (a) and (b) are reproduced by permission of Joseph Lucas Ltd.)

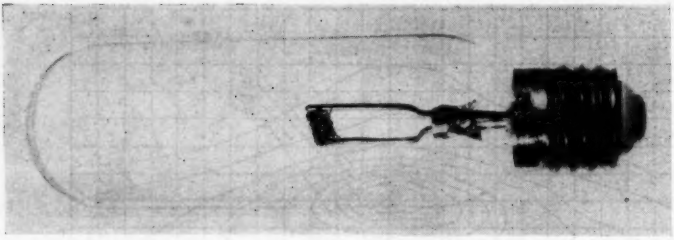

Fig. 4. Coiled-coil filament lamp.

Table 2

Lamp Type	Bulb	Diameter	Use
		mm.	
12 volt 600 watt	Tubular	63	Marine Searchlight
24 volt 250 watt	Round	78	Loco Head
24 volt 500 watt	Round	78	Cloud Searchlight
24 volt 900 watt	Tubular	63	A.1 Projector and Marine Searchlight
24 volt 36 watt	Round	38	Headlamp
12 volt 36 watt	Round	38	Dome Silvered Morse Signalling Lamp
6 volt 12 watt	Tubular	15	Admiralty Gunsight Lamp

(5.2.3) *Coiled-Coil Filament*

The low voltage coiled-coil filament construction makes possible the production of a practically spherical light source as shown in Fig. 4. Lamps of this type are used with lens and mirror systems to produce beams of small divergence for spotlamps, small searchlights and the like. Table 2 gives particulars of a few selected types and indicates their normal use.

(5.2.4) *Solid Source Filaments*

The solid source filament arrangement is a development of the line filament but makes use of the fact that if a number of low-voltage filaments are mounted electrically and mechanically in parallel with one another and are carefully lined up they can be allowed to touch one another and little or no circulatory current occurs. As a result rectangular filament formations may be obtained of high average brightness and a high degree of uniformity over the filament area.

(5.2.5) *Other Filament Designs*

Other well-known filament designs include the simple bow, the "V" and the twin pillar filament in which a short coil is bent back on itself so that two limbs of the coil lie parallel to each other and close together. These various forms of filament can be mounted either axially within the bulb, at right angles to the bulb axis or with special displacement from the axis. An example of this type of mounting is shown in Fig. 5 in which the lamp filament is brought as near as possible to the lamp bulb without risk of softening the bulb. This construction was designed to allow the light source itself to be brought very close to the first collecting lens of an optical system so increasing the efficiency of light collection. Naturally bulbs of very hard glass are required and forced air cooling is often employed.

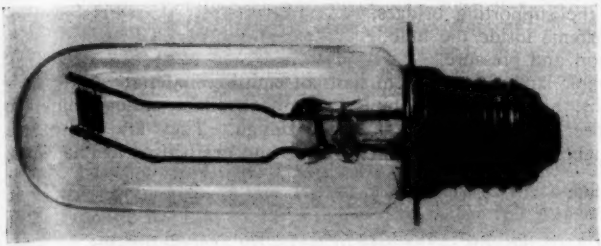

Fig. 5. Pathé projector lamp with filament near bulb.

(5.3) Projection Lamps—Medium and High Voltage Types

Tungsten filament projection lamps can be made to operate from any desired voltage. Apart from the low voltage range briefly mentioned above, the chief voltages employed are around 110 and 115 volts and between 200 and 250 volts. In general, projection lamps are easier to make in the 110-115-volt range than in the 200-250-volt range. There are, however, a number of very efficient types available in both classes.

In this country the use of medium voltage lamps generally necessitates the provision of a step down transformer or some equivalent device for providing the correct terminal voltage. High voltage lamps operate directly from the mains supply. In some of the earliest designs a continuous filament coil rather similar to that used in the household type lamp was wound on to molybdenum support wires to form a flat grid as shown in Fig. 6. The same figure shows a filament made as a series of segments so that light is emitted only from the parallel segments of the grid. As filament wire of greater stability was developed, it was found possible to make the grid formation still more compact and eventually the bi-plane filament was produced. Each of these forms is illustrated in Fig. 6.

It is worthy of note that the bi-plane projection lamp with its compact high brightness filament represents one of the highest forms of the lamp makers' art. It has only been achieved by careful study of the many factors which influence the stability of the filament which must remain rigid at a temperature of 3,000 deg. K while its various parts are separated by only a millimetre or so.

Some of these factors are:—

Type of tungsten filament wire,
Crystal structure and heat treatment,
Geometry of the primary filament coil,
Mandrel diameter, pitch and filament spacing,
Expansion characteristics of the whole filament supporting structure,

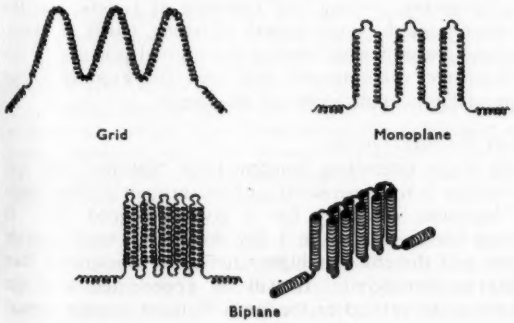

Fig. 6. Filament coils.

Insulation of the supporting bridges,
Convection currents inside the bulb,
Gas composition and pressure,
Freedom of whole lamp interior from spots of emitting material.

The highly efficient, high brightness biplane lamps available to-day must be handled with due respect to their construction and design. They are one of the precision tools of the lighting industry, accurately made and prefocused to fine limits.

(5.4) General Lighting Lamps

(5.4.1) *Bulb Finishes*

Noteworthy among developments in the field of lamps for general lighting purposes has been the introduction of bulbs with new surface finishes. Perhaps the most important of these is the silica-coated lamp which combines a high degree of diffusion with very low absorption. This development is of great intrinsic interest insofar as the degree of diffusion can be almost complete, and yet the percentage transmission of the incident light may be very near to that of a clear glass bulb. It is unlikely, therefore, that any more effective method of producing diffusion can be developed, although a similar result might be obtained by other means and the manufacturing processes involved are subject to continuous development.

(5.4.2) *Coloured Bulbs*

From the very early days of the incandescent lamp industry, coloured glass bulbs have been utilised for producing special lighting effects. With vacuum type lamps of the old cage design, coloured lacquers were very useful for coating the outside of the bulb of the finished lamp. Coloured silicate coatings have found extensive use for sign lamps and for many other types of lamp where the effect of a coloured opalescent bulb was desirable. Methods were then worked out for producing bulbs with a suitable colour sprayed on the inside surface.

The latest development is one in which transparent or translucent enamels or other coloured finishes are fired on to the glass bulb before lamp manufacture, and most useful and beautiful effects can be produced. Not only are these finishes suitable for sign lamps and lamps of the general lighting type, but they are also being applied to special reflector spotlamp bulbs and the like.

(5.5) Special Lamps

Mention of reflector spotlamps in the previous section illustrates the growing use of special lamp types in fields in which previously electric lamps found no widespread use. For example, the infra-red drying lamp has an important part to play in modern industry. Its widespread use for chicken and pig rearing is not perhaps so well known. These applications arise from the well-proven benefits of providing safe and controlled artificial heat for the farrowing, rearing and fattening of piglets, and the constant warmth so necessary to encourage the rapid growth of strong, hardy chickens. It could be argued that these matters are somewhat outside the normal practice of the illuminating engineer, but as important examples of new uses for existing lamps they may stimulate investigations of lamp applications in new fields.

(5.5.1) *Lighthouse and other High Wattage Lamps*

Lamps in this category have many interesting constructional features. As was indicated in the section on low voltage lamps, increased current through a lamp leads automatically to an increased luminous efficiency for a given designed life. It therefore follows that high wattage lamps—say, from 1 kw. to 10 kw.—will operate with higher filament temperatures, and therefore at higher luminous efficiencies than the smaller types of lamp hitherto considered. It will be appreciated that the relatively large currents which have to be carried to the lamp filament require special

hermetic seal arrangements, and much ingenuity has been exercised in developing multi-wire pinches, special alloy seals and developments of the well-known "bi-post" principle. There are two main types of "bi-post" seal, one in which a feather-edged copper thimble is sealed directly into a hard glass base, and the other in which the sealing thimble is made from an alloy well matched in expansion characteristics to that of the glass base. By this means currents of 100 amperes or more can readily be handled.

Much development has taken place in the evolution of special filament constructions for use in high-wattage lamps, particularly of the lighthouse and beacon types. The reader is referred to the original papers for full information, but there is one filament construction which is perhaps worth mentioning; this is one developed for signalling directly by interrupting the main current through the lamp. The nigrescent and incandescent periods of the quite thick filaments used in high-wattage lamps makes such signalling either impossible or only possible at very slow rates. This difficulty can, however, be largely overcome by constructing the filament from a number of low-wattage units built up in parallel. The much thinner wire of each low-wattage component has a natural period of incandescence and nigrescence compatible with slow morse code signalling rates, and the combination of a number of such filaments in a single bulb allows this property to be extended to high-wattage lamps. The lamp is shown in Fig. 7.

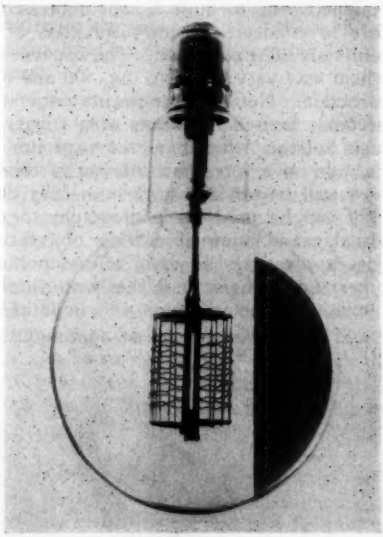

Fig. 7. Quick nigrescence lamp.

Besides their primary use for signalling purposes, these rapid nigrescence lamps, as they are called, have possibilities for lighthouse and beacon work. It should be noted, however, that this property is achieved only at the expense of efficiency, as the efficiency for a given designed life is a function of the wattage of the individual parallel component members.

(5.6) Gas Discharge Lamps

The use of simple gas discharge tubes for advertising and display purposes hardly needs mention in a paper of this type. Very high-voltage tubes, however, were among the earliest of electric lamps, although in the beginning their efficiency was

so low that they were regarded more as laboratory toys than light sources. None the less, from these simple beginnings—and particularly after the isolation and production in commercial quantities of the rare gases—came the neon sign tube and all the developments which flowed from it.

Here we are primarily interested in the discharge itself and in those developments which were brought about by utilising much higher gas pressures than are used or desirable in high-voltage cold-cathode lamps. Analogy with high-pressure metal vapour lamps suggested that particularly with rare gases of high molecular weight it should be possible to obtain higher luminous efficiencies than were obtainable with the high-voltage types. This proved to be so, and at the present time xenon is used in most types of high-pressure gas-discharge lamp of either the intermittent or continuous burning kind. The intermittent type of xenon lamp, or repeating flash tube, as it may be called, utilises the principle that a suitably designed tube with electrodes at each end containing a gas at high pressure is virtually non-conductive up to quite a high impressed voltage. The method of operation is therefore to connect a xenon-filled glass or quartz tube with short, heavy leads to the terminals of a capacitor. The capacitor is then charged to a relatively high voltage which may vary between, say, 500 and 5,000 volts, according to the result it is desired to obtain. No discharge occurs until at a pre-determined moment of time the xenon becomes ionised by means of a trigger electrode connected to a separate source of high voltage, whereupon the capacitor discharges its content of electricity through the tube in a very short interval of time. The results obtained by this procedure are now well known and have been fully described in the literature. The single flash of light can be used for photography, or, when produced at regular intervals, for the visual examination of moving objects by stroboscopic arrestment. By such means, flashes effectively as short as one millionth of a second have been obtained; at the other end of the scale flashes with a duration of a few milli-seconds and with a peak luminous output of some thousands of millions of lumens are possible.

The class of gas-arc or continuously burning high current density gas discharge

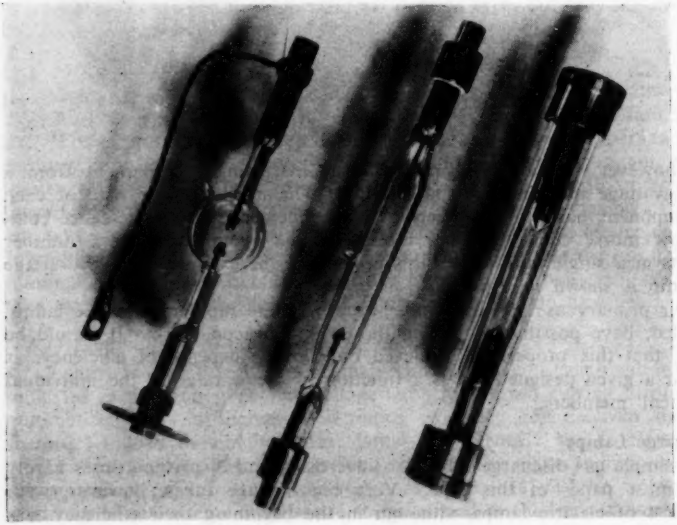

Fig. 8. Range of gas arc lamps.

tube is receiving increasing attention and applications include colour matching units, light sources for colour photography, projection, plant growth acceleration, accelerated fading tests for dye-stuffs and many others. A range of typical gas arc lamps is shown in Figure 8.

(5.7) Metal Vapour Lamps

Just as with the pure gas discharge lamp, so the modern high-pressure metal vapour lamp has its roots in the beginnings of electrical developments. The mercury vapour lamp of Cooper Hewitt was developed by Kuch in 1907 into a short compact form similar to the high-pressure mercury vapour lamps now used so extensively for street lighting but without the reliability, high output and long life of the modern lamp.

The sodium lamp has been compared with the mercury vapour lamp in its present form, although from the point of view of pure physics it should strictly be compared with the very low pressure mercury vapour discharge which is employed so effectively as the ultra violet source in fluorescent lamps. The structure of the sodium atom is such that the resonance radiation which is produced when sodium is excited lies in the visible spectrum, producing the well-known yellow lines which are responsible for the bulk of the radiant energy from the sodium lamp.

Increased current density which leads to higher vapour pressures is detrimental to the efficiency of light production, as with too high a pressure absorption of the sodium resonance radiation occurs and more heat is produced at the expense of light.

The fundamental difference between the modes of operation of sodium and mercury lamps arises from the fact that with mercury the resonance radiation is in the ultra-violet region and the development of a high efficiency lamp depended on arranging the conditions inside the lamp so that the resonance radiation was absorbed and re-emitted as visible light. These matters are now part of the history of discharge lamp developments, but it is surprising how imperfectly they are understood at times. As the pressure of mercury vapour is caused to increase by allowing the bulb temperature to rise, the voltage drop across the electrodes of the lamp increases and for a given designed voltage the arc length can be decreased. This decrease can be carried to a point at which the arc may be only 1-5 mm. in length as in the ME-type lamps. Naturally the dissipation of a considerable wattage in an arc only a few mm. in length leads to the emission of considerable luminous flux from a very small area and therefore a very high brightness source is produced.

The number of types of high-pressure mercury vapour lamp which are now available to the lighting engineer is surprisingly large. It can justly be claimed that the lamp research laboratories in Great Britain have led the world in this field. The medium pressure mercury vapour lamps and the smaller high pressure quartz types have enabled important contributions to be made in street lighting and area lighting. Water-cooled high-pressure lamps and the air-cooled short arc types have found a wide variety of uses. The smaller wattage ME lamps in particular have become established as important sources for many projection purposes.

(5.8) Fluorescent Lamps

In the fifteen years or so since its introduction, the fluorescent lamp has found almost universal application for general illumination purposes. It is this fact which distinguishes it from any other form of discharge lamp.

Compared with the tungsten lamp, the fluorescent lamp with its associated control gear is comparatively complex. In general, however, the control gear is now so reliable as to be almost forgotten once it has been installed. The fundamental advantage of the fluorescent lamp is to be found in its truly astonishing performance measured in terms of effective lumen hours. This will be clear from the comparisons in Figure 9 which show graphically effective lumen hours for a few ordinary tungsten filament

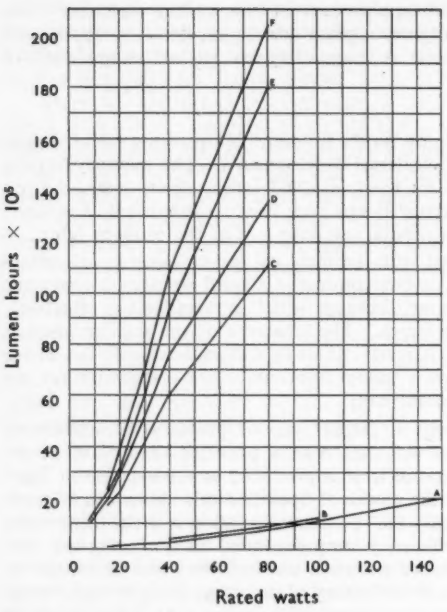

Fig. 9. Light output through life.

A—Single-coil filament lamps.

B—Coiled-coil filament lamps.

C—Mellow, colour matching, white and de luxe warm white fluorescent lamps.

D—Natural fluorescent lamps.

E—Daylight and warm white fluorescent lamps.

F—New warm white fluorescent lamps.

lamps compared with the nearest equivalent fluorescent lamps. It will be seen that for a given wattage the modern fluorescent lamp has between 10 and 20 times the effectiveness of a tungsten lamp assessed in terms of lumen hours output over life.

A second characteristic of the lamp which has, in the author's opinion, contributed to its success is the excellent light distribution resulting from its linear form. This is interesting as many attempts have been made to reduce the size of the fluorescent lamp and to produce a form and shape more nearly resembling that of earlier light sources. The patent literature abounds in developments of this type, which were perhaps always doomed as the user and the illuminating engineer gradually appreciated the advantages of a linear source many times longer than its diameter. There can be no doubt that whatever developments there are in fluorescent lamps for special purposes and special lighting effects—such as the fluorescent circle and the like—the straight lamp will continue to dominate the fluorescent lighting field as the principal type. The majority of lighting applications with fluorescent lamps can be satisfied with the standard length lamps varying from 1½ ft. to 5 ft., while for more specialised applications the 8 ft. lamps find their proper place as do the cold cathode fluorescent lamps.

Of recent years no question has occupied the minds of those engaged in the development and use of these lamps more than the question of colour. At first sight it would appear that there ought to be little discussion on this problem, but in fact it is a subject of great importance and interest. For the first time in the history of the development of light sources it is possible to produce either coloured lamps or near-white lamps with a practically infinite range of colour and colour rendering properties. The position is complicated because (a) for the same colour appearance the colour rendering properties can be varied, and (b) the efficiency of light production is dependent upon the spectral distribution and therefore dependent upon the choice

of colour. To some extent efficiency and colour are mutually exclusive in the sense that for near-white lamps the optimum colour rendering can only be obtained with material sacrifice in luminous efficiency and if maximum efficiency is the criterion then there has to be some sacrifice in colour rendering to obtain this result.

The greatest difficulty of all, however, is not one for the lamp research engineer. It has to do with satisfying the often intangible requirements of the user. With the tungsten filament lamp the user had to take the natural colour of the light source which depended only on the temperature of the filament and therefore the efficiency for which the lamp was designed. There is no automatically occurring colour for a fluorescent lamp and therefore lamps have to be designed to broadly fill a particular field of usefulness.

For this reason the original " daylight " lamps were followed by " warm white " and later by " natural " and " mellow " lamps. Now, after considering many alternatives, a " de luxe warm white " lamp has been introduced by some manufacturers to the British market together with a high efficiency warm white lamp. The " de luxe " lamp is designed to give light which will mix well with tungsten light and will produce similar colour rendition.

Many factors have to be considered before such new sources are introduced. These considerations include not only surveys in the laboratory of new phosphor developments but also such matters as the relation of any proposed new lamp to existing lamps not only in Great Britain but in Europe and in the United States. An obvious ultimate goal is the world-wide standardisation of a small series of agreed colours representing the optimum technical possibilities and the most desirable user characteristics in relation to both efficiency and colour. In the author's opinion no such standardisation is at the present either feasible or desirable as evolutionary developments are still taking place. Nevertheless, regard must always be paid to the ultimate goal in this matter of fluorescent lamp colours where lamp characteristics and user requirements are so intimately bound together.

The fluorescent lamp has found extensive and increasing use in such fields as the lighting of factories, commercial premises, offices, large stores, shops and schools. Its use for street lighting was pioneered in Great Britain as was also its application to the lighting of coal mines and the like. It has been introduced to a small extent into the home and this field in the author's view offers a major challenge to the lighting engineer. It is considered that the new " de luxe " lamp will help towards this end.

(6) Conclusion

That there is a significant need for improved lighting in practically every sphere is indisputable. Sometimes the problem is an educational one. The industrialist needs to be convinced of the benefits of improved lighting standards. This is true not only in production plants and factories but in offices and commercial premises. Home lighting calls for vigorous and special treatment, for here bad lighting conditions are in general the rule rather than the exception. A great deal has been achieved in this country in improving the standard of road lighting but the proportion of well lit roads is still deplorably small. In spite of the advances which have been made—and in many fields Great Britain leads the way—there is still a gap to be closed between the best that has been achieved in all the varied fields in which lamps are applied and the much lower standards which are tolerated in the majority of lighting applications.

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Discussion

MR. W. J. JONES: It is always a treat to hear an exposition by a master and we have enjoyed tremendously the address given by Dr. Aldington and also the demonstrations. It is difficult for anyone to pick out from an address of such breadth suitable subjects for discussion.

He has reminded us of the latest and the newest developments, and at the same time he has taken us back to some of the earliest. I am reminded, because he has referred to them, of those exciting days when discovery followed discovery with electric discharges and fluorescence.

I well remember the first president of the Illuminating Engineering Society enthralling his audiences with demonstrations of fluorescent materials. I remember, too, when he showed us various gems and pearls excited to fluorescence by means of cathode rays.

Dr. Aldington showed us an experiment which reminded me of a part of his paper referring to the fluorescence from X-rays; it took me back many years to when I was working with X-ray tubes, the bulbs of which glowed with a bright apple green fluorescent. The fluorescent screens which we were using gave quite a lot of light in the room.

There are three points I want to comment upon. The first is to support the plea of Dr. Aldington that if there is a lamp which does the job, we should not try to seek something new or special for it. The lamp maker, as you will have guessed this morning from Dr. Aldington's remarks, is called upon to make something like 10,000 different lamps varying in rating, in voltage, in caps, and in finish. We should use standard lamps and standard products as much as possible.

The second point concerns the author's very beautiful experiment with the motor-car headlamp bulb and the nature of the beam of light obtained from it. Here you have an example in which the user has determined the engineering aspects of the lamp itself, and I want to suggest that the problem of beam pattern should be followed up not only in this country, where we have more or less settled its nature, but in the international field also.

There are three organisations involved: the first is the C.I.E., which deals essentially with the illumination problem; then there is the International Electro-Technical Commission, which deals essentially with the standardisation of the bulb itself; and thirdly, the I.S.O., which deals with the position of the fitment itself on the motor-car. It is a complex problem, but we should make a start in order to get these matters really appreciated and put in hand.

I want also to refer to the important section of Dr. Aldington's paper on the subject of fluorescent lamps. He gives a very interesting diagram (Fig. 9) showing the effectiveness of the fluorescent lamp compared with the tungsten filament lamp, pointing out that it is 10 to 20 times as effective if you take into account the lumen

hours. In passing, we might also bear in mind that the fluorescent lamp is even more effective in the production of coloured light. I estimate the advantage there is of the order of between 50 and 100 times.

I was very interested in Dr. Aldington's remarks on the question of standardisation. I, personally, am very glad that steps are being taken to standardise fluorescent lamps in this country. I think members of this Society know that the British Standards Institution has in hand, and it is in an advanced stage, the issue of a specification dealing with the electrical details of the fluorescent lamp; this specification also refers to the important question of colour. The significance of standardisation is not confined to the needs of this country because we are all concerned with selling our products to countries overseas. Our customers expect to get lamps which are comparable, which look alike when they are supposed to be alike. There is also the problem of international standardisation of fluorescent lamps including their colour.

I note the author's reservations on standardisation and I am in sympathy with them, but have the feeling that if we do not start now, we shall get into a chaotic state. It is very much easier to marry trends with standardisation than to attempt to have international standardisation when each of the countries in the world has its own particular standard. I am therefore pleased that the International Electro-Technical Commission will have this question of fluorescent lamps and colours as a major item on the agenda of its meeting to be held in Philadelphia in September and hope the discussions will be advanced to such a stage that when the I.E.C. visits this country next year we shall have made very considerable progress towards international standardisation.

DR. J. W. STRANGE: I would like to support what Mr. Jones has just said on the importance of standardisation. Dr. Aldington, in his paper, remarked that it was neither feasible nor desirable. I feel he may have second thoughts on the exact wording because the efforts which have already been made in the B.S.I. and in the I.E.C. discussions have shown that it *is* feasible within a reasonably limited field.

I think we must approach standardisation along the lines of having a large target to begin with to include the existing manufactures, and aim to restrict that target over a period of years so that we can eventually reach close agreement between different manufacturers. One of the recurring complaints is the extraordinary range of colours which are available, both in this country and—more embarrassingly—in different countries.

I have one other comment on Dr. Aldington's paper. In the discussion of electro-luminescence he suggests that the publicity given to this phenomenon is greater than is justified by its potentialities. Now, I think that is the wrong word. Certainly, its immediate practical *achievements* are limited, but I, for one, would hesitate to estimate at the moment its *potentialities,* which are really unknown.

About a month ago we had a conference at Cambridge of the Institute of Physics and one whole session was devoted to electro-luminescence. It was clear then that the full potentialities of this new source were not at the moment even within the grasp of the theorists. Although its practical achievements are limited, its potentialities are as yet unknown. Certainly, in the last year, it has made substantial advances although at the moment, to my mind, it has a fairly limited application.

I have two other minor points. One is a query on the silica-coated lamp. Some time ago I saw a reference to this lamp in which it was stated that it could be filled with a higher proportion of argon to nitrogen than the normal frosted lamp. I wonder whether Dr. Aldington has seen that reference and has any explanation for it. As far as I know no explanation has been published so far.

My last point is to inquire whether he has any comment to make on the zirconium

arc. It is not included in the paper and it does seem to me to be an interesting source which has a definite though a fairly limited application.

DR. W. J. WELLWOOD FERGUSON: I want to refer to the plea Dr. Aldington made in the introductory remarks he gave us on the supply of light to the human eye. He referred to the perhaps somewhat unfortunate fact that the eye will tolerate working under conditions which are extremely adverse, both at the lower and the higher level, without actually going on what you might call "visible strike."

I have been particularly interested in mine lighting for a large number of years. Even now, with the very considerable improvements which have been made, the miner has to work under conditions of illumination which would not be tolerated, I suppose, in any other industry yet, by and large, they carry on.

Dr. Aldington made the point that in artificial lighting we should try to get somewhere near the visual comfort provided by average natural daylight. From the medical point of view, I think that we should be able to use our eyes for any given task without being aware that we are using them. I think that is the theory we should apply and I think that should guide us to aim at ideals which may be both technically and economically possible.

DR. R. G. HOPKINSON: Dr. Aldington gave us a delightful demonstration of the ability of the fluorescent lamp manufacturer to match the colour rendering properties of filament lamps. I would like to ask Dr. Aldington if he thinks that approach is philosophically sound. With fluorescent lamps we have the opportunity to start right at the beginning to find out, with the aid of a properly designed subjective judgment experiment, what sort of colour rendering people really like and to match it without any reference to gas mantles or filament lamps or candles. Could I ask Dr. Aldington for his views on whether in fact that might be a way of tackling this colour rendering problem?

MR. HOWARD LONG: I feel sure that one of the most outstanding phases of Dr. Aldington's lecture was his putting into correct perspective the standards of illumination in relation to economics. I think it is a very refreshing approach, based on a sound foundation, and if we all go away from this meeting with that thought in mind, we will have achieved something.

The other thing on which I would like to comment relates to standardisation. If the standards are adopted I think we ought to use the correct terminology and there are fluorescent lamps in other shapes than tubular (bulbs) to which no reference has been made in the written paper. There has been some development in those which may well bring them into a very useful form.

MR. W. GILCHRIST: There is still an impression in the public mind that because a light goes on, because it is so apparent, it is expensive; that idea must be eradicated. I would say that a more rational approach is being made to tariffs in that charges are being more closely related to costs. The evidence may be that in this particular area many commercial consumers are paying less for their lighting than they were before the war, and the fact that lighting can be cheap—and is in fact cheap—should be publicised.

I would suggest for the author's consideration that the manufacturers should as soon as possible (a) eliminate clear lamps and (b) produce only 60- and 100-watt lamps for general illumination. By being bold and standardising on two sizes, either silica or pearl, we should be able to produce and sell lamps at the lowest prices.

MR. C. C. SMITH: Dr. Aldington did mention in the introduction to his talk the desirability of eliminating glare and Dr. Wellwood Ferguson, in his contribution,

also said how desirable it was that the eye should see under optimum conditions. I would very much like Dr. Aldington to say why illuminating engineers concerned with lighting interiors are so anxious to avoid glare, in situations where brightness values and illumination values in general are comparatively high, and yet when we come to the streets, where such values are low, there is a definite tendency not to pay so much attention to it.

I would also like to ask the author a question regarding trends of development. I am sure we would very much value his views about the possibilities of the sodium discharge lamp: does he think that it has reached its final form or are developments still possible?

My last point concerns the colours desired, or the colour rendering properties required by people. Dr. Hopkinson did suggest, I think, that it would be practical now, with the fluorescent lamp, to start at the beginning and provide the colour or colours generally desired. This, I feel, is fraught with unknown difficulties, because there are so many individual ideas of colour and many different tastes and preferences and, in my opinion, it is wellnigh impossible to produce a small range of powders to satisfy everybody's taste.

DR J. N. ALDINGTON (in reply): First of all may I thank you for the kindly reception which you have accorded this paper. The chairman has referred to the contributions made by my colleagues, but I alone know how much the paper owes to the help which I have received from Mr. Cumming and his staff. We would also acknowledge the great assistance which we have received from Mr. Illingworth, Street Lighting Engineer of Southport.

I was very interested in Mr. Jones's reminder of the early days of development in the X-ray field because there was a carry-over from some of those developments to the first applications of fluorescence in the field of high-voltage cold cathode discharge tubes. At one time it did appear that developments of ordinary glass, which Mr. Jones noted as fluorescing blue green, would result in a great increase in the fluorescent efficiency under ultra-violet excitation. Special fluorescent glasses were in fact used both for the production of light for illumination purposes and also for producing many effects for display work.

Mr. Jones was perfectly right when he reminded us of the great effectiveness of the fluorescent lamp as a source of coloured light compared with light from a tungsten lamp used with colour filters.

On the question of the standardisation of fluorescent lamps referred to by Mr. Jones and Dr. Strange, I feel that there is no fundamental difference between us. Mr. Jones spoke of the need to try to standardise trends in colour developments, and Dr. Strange spoke of areas of agreement. I have always supported this attitude at meetings of the C.I.E. I agree that we need urgently to get areas of agreement which will include existing lamp colours of types which can properly be grouped together internationally, the eventual objective being to bring down the areas until we have obtained agreement on specific objectives with limits. What I am anxious, however, should not obtain is any attempt to standardise prematurely specific objectives which would have the effect in my opinion of hampering future development in a field where development is still proceeding rapidly.

Again I think that any difference between Dr. Strange's views and my own on the subject of electro-luminescence is largely one of emphasis. I believe that the Cambridge Conference to which he referred and the great interest which was shown in the phenomenon of electro-luminescence was directed at the potentialities of the phenomenon from the research point of view rather than to its potentialities as a method of producing light in a competitive sense. There is no doubt that electro-luminescent phenomena are of great value in the research field in helping us to understand the

mechanism of fluorescence. I maintain the position I took up in the paper that in my view this phenomenon has small potentialities compared with that of the ordinary fluorescent lamp as a practical light source.

With regard to silica-coated lamps, as Dr. Strange will remember, the matter he refers to did receive some attention during the meetings of Committee 21 of the C.I.E. in Stockholm some three years ago. There is in existence, I believe, a patent claiming that a higher proportion of argon to nitrogen can be used in a silica-coated lamp than is possible with the normal inside frosted lamp, but I do not myself know on what the claim is based. We have not found support for it in our own work, but one realises only too often when dealing with physical phenomena that there can be a real effect of this sort without it necessarily being possible for other workers to repeat the result.

With regard to the zirconium arc I would like to clarify my statements made in the written paper. In no sense did I try to produce a comprehensive review of developments in light sources. My purpose was to produce a theme in which I could set down my strongly held views on certain of these modern light sources and their uses and to introduce a few illustrations. The zirconium arc is a minute source—indeed the smallest of all sources of high brightness—and it has a number of interesting applications. It has certain circuit complications however and does not appear to be capable of competing, for example, with small high wattage M.E. lamps. It is one of those interesting developments lying on the border line between incandescence and luminescence. The lamp has a relatively long life, but ultimately the light producing member is consumed by vaporisation.

I was glad of the support of Dr. Ferguson, who has done so much fundamental work in respect of the low illumination values met with in our coal mines and the harmful effects on the eye which are sometimes produced as a result of these low levels. I was happy to hear him speak of the objective of striving for the visual comfort of daylight levels and that we should use that objective to guide our thinking.

Of all the questions which I have been asked the one from Dr. Hopkinson places me in the greatest difficulty and my reply must be taken only as an expression of my personal views. He asked whether I thought that the objective of producing a fluorescent lamp to match the colour rendering properties of filament lamps was the right approach philosophically. In reply I would say that it is obviously one of the approaches which has practical value in so far as it has been achieved in the new de luxe warm white lamp and it allows lighting systems to use effectively these lamps in combination with tungsten lamps. Fundamentally, however, my answer to his question is "No." I believe that in developing an optimum colour for fluorescent lamps we should disregard older sources and their colour rendering properties and look at the problem of colour appearance and colour rendering purely in relation to user reactions. For instance I think there are fluorescent light sources of great acceptability whose colour appearance lies on the purple side of the black body locus. These sources can be highly efficient, have much better colour rendering in the blue region than is obtained with tungsten light and at the same time have a red rendering which is adequate compared with daylight.

I understand that Mr. Long's remarks were directed particularly at possible confusion between fluorescent lamps of the mass produced type and mercury lamps with fluorescent outer bulbs, a similar description being used for entirely different types of lamp. I agree with his remarks. In my paper, by way of example, I have been dealing only with the type of fluorescent lamp of tubular form in which the fluorescent powder is in direct contact with the discharge. Mr. Long has rightly reminded us of the developments which have taken place quite recently in fluorescent powders for use on the outer bulb of high pressure mercury lamps. These new powders allow of the

addition of a material amount of red radiation to the mercury light so increasing the acceptability of high pressure mercury lamps for a number of purposes.

I have a great deal of sympathy with Mr. Gilchrist's recommendations to the lamp manufacturers to strive to reduce the number of types of lamp. I will content myself with saying that if illuminating engineers and users will support the plea of Mr. Gilchrist, I am sure that they will find that lamp manufacturers will be not averse to the simplification he suggests!

Mr. C. C. Smith has raised the intriguing topic of glare. Is not the answer to be found in the fact that on our roads high brightness sources can be used successfully providing they result in large areas of relatively high brightness reflected back from the road surfaces? In the lighting of interiors the visual angle of a glaring source may be quite high owing to the close proximity of the observer to the source. The visual angle of a street lighting lamp is generally much less and therefore may be tolerable having in mind the much larger angle subtended by the high brightness area on the road surface against which the object of regard is viewed in silhouette.

With regard to trends in development I consider that the sodium discharge lamp is near the limit of its development and is an example of my general contention that many of the new sources of the last two decades have apparently passed from the period of very rapid evolution to stable forms.

With regard to his last point I know from Mr. Smith's final comments that he realises only too well the impossibility of trying to suit everyone, especially in the difficult matter of colour. It is however necessary to try to obtain a cross section of consumer reaction to any proposed new fluorescent colour in the constant search for the ideal which is as much an objective of the research physicist as of the user.

The Decorative Approach to Commercial Lighting

By ANDRÉ CLAUDE

Summary

Fluorescent light sources, by their characteristics, have completely upset the classical lighting techniques previously in use and have set new problems in the decorative quality of commercial lighting installations. No decorative lighting for commercial purposes and no luminous sign can be truly satisfactory unless the scheme that is to be carried out by the lighting engineer has in the first place been conceived by an artist pursuing an aesthetic conception regardless of the ultimate purpose of the installation.

The author recommends that fluorescent light sources used in such installations should have a predominantly red spectral emission. Incandescent sources can be usefully combined with fluorescent sources. The completed lighting scheme should include one or more spots of colour, either light sources or lighted surfaces, which serve as tonal points of reference by which the colour value of the general lighting can be located.

(1) In Search of a Definition

However far one goes back in human history, it is noticeable that everywhere men have carried on trade and commerce by night. They showed a natural inclination to make use of artificial light sources in combination with devices of artistic merit which were, for a long time, only brackets or stands worked in wrought iron or in glass.

The development of fluorescent light sources, whether machine made and standardised or tailor made, has led to the introduction of devices in which the classical techniques used hitherto have been completely abandoned.

Fluorescent sources provide white or coloured light in great variety, a considerable increase of illumination and, finally, continuous lines of light. The illuminating engineer is therefore faced to-day with the problem of using these new sources for the production of decorative lighting schemes. There is no doubt that the results actually obtained are sometimes outstandingly successful and sometimes suffer from serious mistakes. The very idea of decorative lighting designed to be used for business purposes does, in fact, involve by definition a contradiction or a paradox which cannot be left unresolved.

The natural instinct of the trader is to expect the lighting to attract the customer, as a moth to a candle, and to show his goods to the best advantage. In other words, the trader wants the illuminating engineer to help him, by means of lighting effects, to enhance the value of his wares.

This idea, carried to its extreme limit, implies that decorative lighting might be used for making fraudulent sales by deceiving the customer as to the real quality of the goods bought or hired. Such a conclusion, however, takes us into the realm of illusion—a subject which lies outside the scope of this paper.

To avoid the mistakes to which I have referred and which so often cause disappointment, we must first recognise that the decorative scheme to be carried out springs, by definition, from the idea of what is aesthetically pleasing. Now, reference to the numerous definitions of "Beauty" show that they depend basically on the production of a psychological effect which is pleasing to the eye quite regardless of any utilitarian aim. So we have to apply means which, fundamentally, are without

The author is chairman and managing director of Claude-Paz et Silva, of Paris. The manuscript of this paper was first received on February 22, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 21, 1954.

material aim, basically to utilitarian human activities, since they are concerned with selling or hiring.

How is such a contradiction to be resolved? It seems to me that it should be done by initial agreement between the commercial client and the architect-lighting engineer. Such an agreement must contain two clauses. The architect agrees with the trader on :

(i) The average value of illumination required, and

(ii) The aesthetic and symbolic lighting theme which will best serve the commercial aims.

Only the second part interests us now.

The symbolic lighting theme having been settled between the client and the architect-lighting engineer, the latter will then carry it out in decorative lighting, enjoying complete freedom of artistic expression and giving no further thought to the trade that will be carried on. This freedom in artistic expression is the key to all decorative lighting.

It will be clear that the final success of the installation will depend upon the quality of the means used for executing the work and on the value of the symbolic theme selected by the client. The greater the harmony between this aesthetic theme and the commercial activities carried on, the greater will be the success of the lighting scheme.

What is to be understood by harmony between the symbolic theme and the commercial activity? Clearly the door is thrown open to a legion of ideas and conceptions in which the artist's talents can be given full play. To make my meaning quite clear, I will select an example which can be carried out very simply, namely, decorative lighting for the clothing trade.

For men's clothing, the architect-illuminating engineer might suggest unostentatious lighting inspired by the simplicity of line and the sober colour of men's clothes. For ladies' wear, on the other hand, with its great variety of designs and colours, he thinks of a shaft of sunlight. In the first installation, he may call for a grey ceiling and a stern luminous atmosphere. In the second, he might demand an open ceiling with the light flowing in enlivening the hues and fancies of the ladies' dresses, like a ray of sunshine on a garden of flowers. In both installations there is harmony, but each lighting scheme freely expresses its own idea; neither is made subservient to the objects illuminated.

Now that the problem has been formulated, let us examine the lighting materials, corresponding to the palette and brushes of the painter, which are provided by the lamp industry for the use of the artist in lighting, so that he may achieve the results which he has undertaken to produce.

(2) Colours and Whites

The psychological influence of colours was known to man from very early times. Primitive men even assigned to them a certain divine significance. The greatest minds of early civilisations put forward colour theories, but after Democritus, Aristotle and Pliny there was no progress until Newton and the development of spectrography enabled us to master, both experimentally and theoretically, this marvellous range of visible electromagnetic waves.

On the sure data provided by physical science, biology can at last make progress in the exploration of the psycho-physiological field which involves both the physiological behaviour of the eye and the psychological interpretation of colours. It is to be noted that, in the present state of our knowledge, the Young-Helmholtz trichromatic theory still seems to hold the field. It is justified, particularly by the very important work of your fellow-countryman Le Gros Clark, the anatomist, who,

in the neural pathway from the retina to the cerebral cortex, connects three pairs of cellular layers in the lateral knee-like body with three colour sensations, red, blue and green.

Be that as it may, the problem with which we are concerned, namely, that of colour in decorative lighting, has really only arisen since the advent of the tubular fluorescent lamp. While it is true that by using colour filters with incandescent sources it has been and still is possible to make play with coloured light, in actual fact this has hitherto been confined mainly to theatrical performances. The use of these theatrical methods in the lighting of commercial premises, however, has generally been considered to be in bad taste, and for these applications unmodified tungsten lighting is nearly always used. Occasionally, discreet touches of colour are added by means of lamp shades.

In contrast to the substantially constant spectral quality of the light from tungsten filament lamps, we have a wide variety of possible spectral compositions from fluorescent sources, resulting from the diversity of the phosphors which have been developed and the mixtures which can be made.

As a result, a question which previously interested only a few specialists has now become generally important, viz., the question of what is white light. All the manufacturers of fluorescent lamps have claimed that they possess the recipe for the ideal fluorescent white light and thus there have been born into the world, with varying fortunes, warm whites and cool whites, daylight whites and evening whites, golden whites and glossy whites, medium whites, x, y, z whites and, finally, just plain whites.

An heroic era indeed, which has been marked in civilised countries by the indignation even of educated people who often thought and said that we were unable to make a fluorescent lamp emitting really white light, or else that we were trifling with them. The limit was finally reached when we were accused of introducing into our lamps, in order to make our fake whites, noxious substances liable to decimate the human race!

We have thus been led by force of circumstance to believe a familiar French proverb which declares that "Tastes and colours should never be discussed." Nevertheless, a general controversy has started on tastes and colours, and a fundamental principle has been raised, a principle which, in our opinion, governs the whole question of what constitutes satisfactory decorative lighting. This is the principle of the universal and immediate formation of a favourable opinion.

What I mean is that a lighting scheme is decorative and aesthetically successful only if it can immediately command the warm approval of most of the people who happen to look at it, i.e., the customers and, more generally, the public, since those places where trade is carried on are usually completely open to the public.

We have put this proposition to the test in a very large number of installations of great variety. Among them let me choose one which is particularly illustrative. Let us consider the lighting of the "Salon de l'Automobile" in Paris which takes place every year at the beginning of October and which, in the space of only ten days, is visited by over a million people. The lighting of this Salon, which is carried out afresh each year and which has for its essential aim promotion of the sale of cars of all types, both French and foreign, is only decorative if the majority of the visitors, if not all, find that the lighting is aesthetically satisfying immediately they enter the doors.

This essentially psychological condition which depends on the mysterious harmony between retinal perception, the impressions by the cortex of the brain and our centres of artistic feeling is always found wherever the effects of light are considered to be things of beauty. This is so, for instance, during a cruise when

The travellers hurry on deck to share a general and spontaneous feeling of admiration as they look at the fleeting effects of a sunset.

Finally, it is by this principle of spontaneous and unanimous appreciation that, after so many years of the most diversified commercial lighting by means of fluorescent sources of varied spectral composition, the public itself, by successive and unequivocal votes of approval or disapproval, has selected fluorescent shades which are aesthetically satisfying for lighting purposes.

There is no doubt about this selection in France. All shades of white with a predominant emission in the blue and yellow parts of the spectrum are rejected as fundamentally inartistic. This means, for example, that "Daylight" lamps are unsuitable for commercial decorative lighting. All the shades chosen and recognised as aesthetically satisfying are characterised by a predominance of emission in the red part of the spectrum; this is, however, only a matter of degree, since the continuous emission from fluorescent powders covers the whole of the visible spectrum.

In France the selected shades are known as "Blanc Z," "Rose de France" and

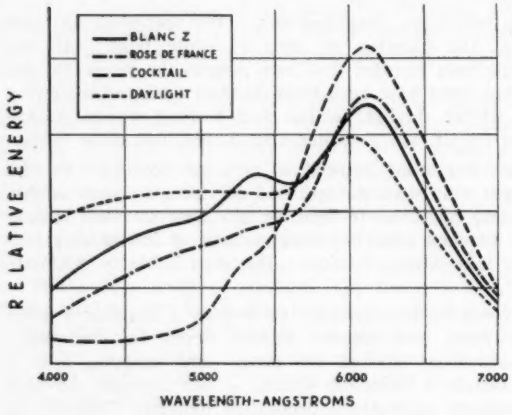

Fig. 1. Spectral energy distribution curves of fluorescent whites (French) for decorative lighting.

"Cocktail." Some of the new American colours, such as "Cool White de Luxe," and "Warm White de Luxe," are similar to these French colours. Our three shades, "Blanc Z," "Rose de France" and "Cocktail," have one thing in common—they are trichromatic. They contain the same phosphors but in different proportions. In all three the spectral energy increases on going from the blue to the green and from the green to the red (this avoids the objectionable purple effects). They differ from one another in the proportion by weight of the red phosphor; this is 63 per cent. for "Blanc Z," 70 per cent. for "Rose de France," and 90 per cent. for "Cocktail" (Fig. 1).

All this means that in practice there is undoubtedly a steady shift in public taste towards a quality of white which may be described as that of the light given by a candle flame. We cannot now decide from this fact whether the candle flame has some mystical virtue or whether our preference is the result of heredity!

Although clearly the spectral curves are not alike, the fact remains that in the region of psychological perception the lighting effect given by a candle flame is especially satisfying, and at the same time this choice, which provides the best solution for commercial decorative lighting also, in my opinion, paves the way for the development of domestic lighting in the immediate future.

Among the tests made, it is worth while recalling one which was especially con-

clusive. It was that arising out of the lighting of the liners "Liberté" and "Antilles." The selection, which was carefully prepared by the responsible authorities in the French Line, was based on the criterion that male and female passengers should, without exception, be satisfied with the effect of the lighting on themselves, on surrounding objects and, in the dining saloon, on the dishes and beverages offered them.

To-day both liners are completely equipped with "Cocktail" fluorescent lamps and, as a matter of experience, neither the pursers nor the stewards have ever reported a criticism of any kind from the tens of thousands of passengers who have been carried. To have solved satisfactorily all the aesthetic problems raised by the effect of lighting on tintings, on fashionable make-up and the colours of dresses, as well as on the hue of a Meursault wine in a Baccarat crystal glass, of Marennes oysters, or of lemon on a Limoges china plate, certainly marks a decisive stage in achieving success in fluorescent decorative lighting.

(3) Fluorescence and Incandescence

Having thus determined the spectral quality of those fluorescent lamps which, when used alone, can provide an acceptable decorative effect, we now turn to another problem as important as the first—that of the part which may be played by tungsten lamps in a fluorescent lighting system.

We have analysed several hundred commercial lighting installations which are undeniably decorative. We have found that in eight out of ten, tungsten lamps are associated with the fluorescent lamps.

Does this mean that this very frequent association is characteristic simply of a transition period from the tungsten era to that of fluorescence? I do not think so. The association of these two kinds of light emission lends itself to the production of an undeniably aesthetic result. To start with, even a small amount of light from tungsten lamps gives the fluorescent light a colour correction which is satisfying to the eye, especially when the articles illuminated are living organic things, human, animal or vegetable. The same is true for foodstuffs.

A further point is that the two kinds of light need not be completely mixed. Mr. André Vigneau, a great artist in light, who is now head of the artistic department of French television, explained at the last meeting of the Association Française des Eclairagistes that in the studio he likes to illuminate the stage settings with fluorescent lamps, while the actor, standing in front of the décor, is illuminated by tungsten lamps. In this way he produces a three-dimensional effect.

The establishment of these facts greatly simplifies the use of apparatus for light control; it provides opportunities for the design of a great number of lighting fittings in which tungsten lamps are associated with fluorescent lamps (Figs. 2 and 3).

From the engineer's point of view the association of the two light sources is especially fortunate as the tungsten lamp can act as the ballast for the fluorescent

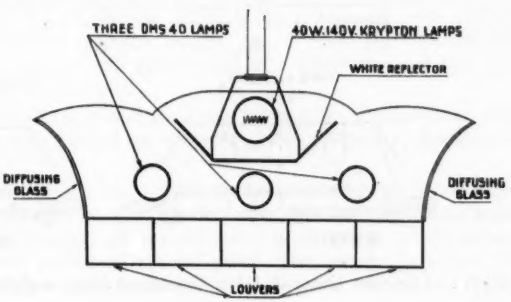

Fig. 2. Cross-section of a luminaire using DMS 40-w. fluorescent lamps to give semi-direct lighting and krypton tungsten lamps to give indirect lighting.

lamp (Fig. 4). One way of achieving this is to put a tungsten lamp in series with the fluorescent lamp, provided the latter will start instantly at the low voltage of the supply, i.e., 220-250 volts.

Initially we solved this problem of instantaneous starting by using fluorescent lamps with auxiliary electrodes, but experience has shown that this arrangement is not satisfactory since the luminous flux from the tungsten lamp is too great in relation to that given by the fluorescent lamp.

On the other hand the use of tungsten lamps as ballast for 4-ft. 40-watt fluorescent lamps with continuously heated electrodes has proved entirely satisfactory. We have named this arrangement with continuous heating of the electrodes the " DMS system."

This system has led to increasingly important developments in France, and the following comments may be of interest:—

(i) This system is only of value commercially when krypton-filled tungsten lamps are used. It will be clear that from the point of view of maintenance, having regard to the life of thousands of hours given by fluorescent lamps, it is impossible to use them with tungsten lamps which have a life of only 1,000 hours. If krypton lamps are used these can be operated at the same colour temperature as the corresponding argon lamps, and under these conditions a life of several thousand hours is obtained.

(ii) The arrangement of our D.M.S. circuits is such that instead of a single lamp two krypton lamps can be used in parallel. These lamps can be selected from current production; for instance, the 140-volt rating is convenient for a supply voltage of 220 volts. The advantage of having two lamps in parallel is not only that from the point of view of geometrical arrangement there are two tungsten lamps for each fluorescent lamp, but also that if one tungsten lamp fails the fluorescent lamp continues to operate with the other lamp, although the output is reduced.

These important results are to a large extent responsible for the installation in France, by the Société l'Air Liquide in collaboration with us, of a plant capable of producing 200,000 litres of krypton annually. This plant is now in operation.

Fluorescent lamps and krypton-filled lamps can be arranged in lighting fittings or in architectural features in very many ways, giving wide choice to the artists. (Figs. 2 and 3.)

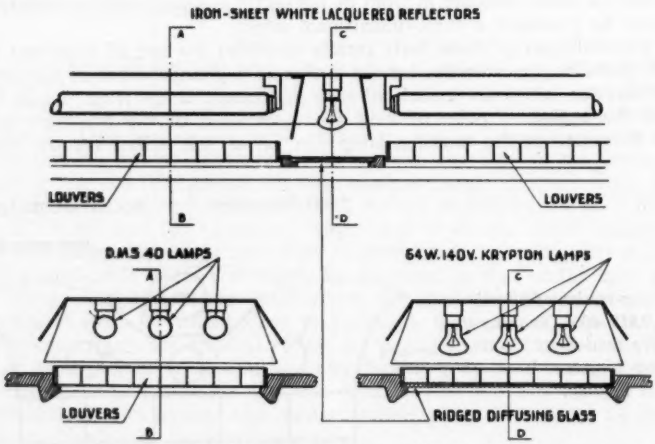

Fig. 3. Luminous line with DMS fluorescent lamps stabilised with krypton tungsten lamps.

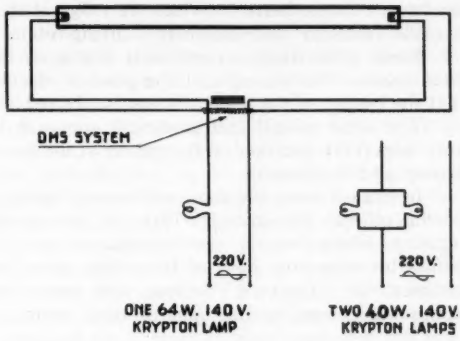

Fig. 4. Stabilisation of a DMS 40-w. lamp by krypton tungsten lamps.

(4) Patches of Colour

Even when the hues of the fluorescent lamps have been settled and their use in association with filament lamps decided upon, and all this has been recognised as necessary in order to obtain a decorative effect, something more than scrupulous care in following the illuminating engineer's recommendations is needed if the decorative result is to be satisfying. Of this there is no doubt.

At the beginning of this paper I suggested that the result obtained could only be decorative in so far as an artistic symbolic theme controlled the way in which it was worked out. I gave as an example the Salon d'Automobile, the lighting of which is changed every year. Every year the lighting of the Grand Palais is a completely satisfying decorative scheme because the illuminating engineers who carry out the work do so under the direction of an artist, the great architect Mr. André Granet.

In addition to these factors of fluorescent colour and the combination of fluorescent and tungsten lighting, can we detect a further common factor of a technical kind which is used by the artist in carrying out his work of decoration with light?

If we study a large number of recent installations of commercial decorative lighting put up in France we shall, I think, be able to pick out a means of expression which is common to them and which may be defined technically to some extent. I refer to what may be called the "patch of colour."

In the whole illuminated area there are, as variants, points, or one or more surfaces, large or small, whose colour presents to the eye a contrast with the general tonal effect of the installation. Such a patch or patches are obtained either by means of coloured fluorescent sources which are directly visible, or with objects lighted indirectly by these coloured lights, e.g., tapestries, artificial windows, or flowers. When these patches are bluish (obtained, for instance, by the use of "daylight" fluorescent lamps) they emphasise the warm tone of the general lighting; when they are red they create the impression of a sunny atmosphere.

An analysis of these very important effects produced by patches of colour leads to the conclusion that a similar part is played by tungsten lamps in general fluorescent lighting schemes.

It appears that this technique, which lends itself to the creation of extremely fine artistic effects, does not depend directly on the laws which govern simultaneous colour contrasts. Without trying to interpret the process of visual sensation, it would appear that these patches of colour serve rather as a tonal point of reference by which the colour value of the general lighting can be psychologically located. In our perception

it acts as a datum mark by which we judge of the general lighting of our surroundings, like the coloured lamp-shade in a living-room.

Some quite simple experiments enable us to analyse these very important visual phenomena. For example, if the patches of colour are suppressed there is no doubt that the beauty of the general scene is affected.

The same critical and analytical approach should be used when considering the very important question of the colour of all the objects to be lighted, furniture, walls, ceiling and hangings.

In France more and more attention is being paid to this lighting and to the colour of the objects illuminated. Thus, in an installation for a room where a piece of tapestry, which may by itself produce a colour patch, is being designed, the artist makes his sketch by light of the colour given by the fluorescent lamps selected (for instance, the "Cocktail" lamps), and before weaving is begun the coloured wool skeins are chosen by the light of these lamps.

(5) Luminous Signs and Advertising

The luminous sign is, without doubt, a part of commercial decorative lighting. It is the external part, pushed forward and thrown like a piece of bait on the ebbing and flowing waters of the human tide. Luminous advertising is only a superior form of luminous sign. The difference is that as a rule luminous signs are removed from commercial premises, mounted at a greater height and are of considerable size.

In towns and on the roads the luminous sign is a beacon, a light signal with many functions. In the first place it serves as a guide for night traffic and takes the place of street name-plates and house numbers, which in France are not always visible at night. (Conversely, from considerations of symmetry, roof signs should not be visible by day). It distinguishes the trade carried on. It is a luminous symbol which can indicate the tone and quality of that trade. It is a promise that what is advertised will satisfy the wishes and needs of the buyer. This beacon can be restrained, refined, appealing, attractive, realistic or poetic, but it must, above all, be decorative. We all agree that ugliness can never be condoned.

It is on this theme of "beauty" and "ugliness" in signs that a battle has been waged in France for the last 40 years between the traditionalists and the moderns. The traditionalists say: "Let us ban signs because they are ugly." The moderns reply: "Signs can be decorative; they promote business, which means prosperity and life. We cannot always live in the past."

Only a real war, by reason of civil defence precautions, can cause the suspension of hostilities to the satisfaction of both sides. The traditionalists are, of course, gratified by the complete blackout. Historic sites may be bombed, but they are preserved from the ugliness of the neon sign. The moderns have on their side all the unfortunates who long every night for the relighting of the neon signs, symbols of peace, of the joys of life and, probably, of the removal or—at least—the slackening of restrictions.

What is the state of hostilities in Paris in 1954? In the first place, certain so-called "classified" zones, with boundaries defined like small national parks, are barred to signs. Elsewhere, notwithstanding severe regulations vigilantly enforced, there are luminous displays which are undeniably aesthetic in character. These signs, these authorised advertisement hoardings, have been harmonised, both in conception and in execution, with decorative lighting schemes, especially in regard to the quality of the whites, the use of patches of colour, and the artistic character of the design; moreover, all this is in scale with the dimensions and lay-out of the streets, the buildings, the squares and circuses.

In this matter of aesthetics a very important and valuable piece of work has undoubtedly been accomplished, and for the first time a bridge of fruitful under-

standing and of mutual respect has been built between the first-class minds and the men of goodwill who, fortunately, are to be found in both the opposing camps.

In brief, luminous signs and advertising in the Paris of 1954 show clearly the supremacy of white or slightly coloured fluorescent hues, the disapproval of vivid colours and the triumph of order over kaleidoscopic fantasies.

Whatever may be the charm of those fairylands of light to be seen in certain cities in the world, we are inclined to think that even the most beautiful colours, if displayed in confusion, do not give the same pleasure as, for example, the lighting of the Place de l'Opéra at night. The arrangement of the luminous advertisements, their artistic design, the colours of the lamps used and the way they are distributed over the area give the effect of outlining in luminous white chalk the boundaries of the Place, the harmony of the buildings and the layout of the surrounding streets, while a patch of colour—that of a distant red neon tube at the Palais Royal—shows up the perspective of the Avenue de l'Opéra. There are in many of the streets and avenues in Paris to-day installations which, although on a more modest scale, are the same in conception and in execution. For instance, in the Champs-Elysées, the Marlène shops and the Lido entrance portico have been treated along the same artistic lines.

This design is geometrically balanced and is executed in white fluorescent lamps. Lanterns introduce a note of lighting with tungsten lamps, while the Lido sign brings in a patch of colour. It is a picture in harmonising colours by means of which the artist, who has clearly given free rein to his powers of tasteful expression, has conjured up the renowned beach, its climate, the sea, the gondolas and the Italian music. Nothing here is really utilitarian; the only aim is to please the eye.

We may note, finally, that the tailor-made lamps used in France to produce patches of colour do not normally give saturated colours, like the green zinc silicate tubes. They are lamps of " pastel " shades, that is to say, whatever the colour selected, the fluorescent light always has a white background on which the colour is superimposed.

(6) Conclusion

No commercial decorative lighting and no luminous sign is effective unless, first of all, the scheme which is to be carried into effect by the illuminating engineer has been thought out by an artist, an architect, in pursuit of an idea, a vision, an aesthetic concept expressed with complete disinterestedness.

The luminous elements used to realise such designs to-day are mainly fluorescent lamps with a spectral distribution in which red predominates and in which there is no excess of blue or of yellow light. Tungsten lamps are also used, generally in combination with fluorescent lamps.

The whole luminous device includes one or more patches of coloured light, the colours of which will immediately locate the general lighting scheme on the plane of psychological perception.

Discussion

MR. A. G. PENNY : During the past few years we, in the I.E.S., have been privileged to hear many eminent speakers from abroad but, even so, I feel that I am not exaggerating when I express the opinion that M. Claude's command of the English language is outstanding.

Turning to the contents of your lecture, M. Claude, I find there are so many points of interest that I, as the first speaker, must not risk monopolising the whole of the discussion by talking about all of them, but I feel I must comment on your remarks about the collaboration between the artist, the architect, the lighting engineer and the client.

In the last year or two we have listened to a number of eminent artists and architects on this theme, and very competent people they have been. Their arguments

have always seemed to me, as a complete ignoramus in these matters, to be most convincing yet, although they have all virtually said the same thing—"Go and do as I do"—their interpretations of that theme have been so widely different that I have felt that if I went and did as each one of them did, the various results would be so vastly different that I should find it difficult to believe that any of them could be right. Of course, once you begin to wonder which one of several alternatives is right, you very, very quickly come to the conclusion that probably none of them are.

M. Claude, right at the beginning, helped me tremendously in that respect because he indicated that the trained artist would submit to the client a number of symbolic themes, all of which might be regarded as adequate for the purpose, and would then discuss with the client their respective merits. From his illustrations, I am beginning to see how completely different themes can, nevertheless, all be adequate for a particular purpose.

I was helped in this by the discussion yesterday afternoon on industrial lighting, when we were, with complete confidence, contemplating the idea of lighting systems using either lamps only a few inches long giving 50,000 lumens or lamps 8 or 10 ft. long giving a couple of thousand lumens. I am not quite sure whether the authors yesterday would have individually agreed with me that all four schemes were adequate but, broadly speaking, if any client had bought any one of those, I think he would have had little cause for complaint. But I can see that if an artist had been in here yesterday afternoon and knew nothing about lighting, he would have found it difficult to believe that a scheme using 1-kilowatt mercury lamps and a scheme using cold cathode fluorescent tubes could be equally satisfactory. Certainly, I think he would have found the differences as difficult to understand or to comprehend as I have previously found the differences in themes put forward by the artist.

Having got that far, I would like to ask how M. Claude integrates the artist and the lighting engineer. Does he do it by a team of artists and engineers or is he able to train one man both as an artist and as an engineer?

Whatever the system in France, I think it does bring home to us here in England the necessity for reviewing our requirements and our standards for the Registered Lighting Engineer. I feel that we must think about revising our standards because I am not sure that, with the present qualifications, a client could come to any Registered Lighting Engineer of the Illuminating Engineering Society and feel quite confident that he could get from him a scheme which would not only provide good lighting but one in which the artistic side would be adequate.

I must record my agreement with M. Claude's remarks about the importance of being able to use tungsten and fluorescent lamps together to achieve decorative results. I think it is only too obvious that for proper use in the decorative field we want small sources and we want large sources. We cannot get incandescent lamps which are many feet long and of low brightness, and we cannot get fluorescent tubes which are of a high brightness and small size, so we must use tungsten and fluorescent together.

In his paper, M. Claude put a good deal of emphasis on red radiation from fluorescent tubes but I would say that our own experience here with our rather prosaic "Mellow" (which is not very different from "Cocktail") is that we need to give a great deal of attention, when it is used with tungsten, to the problem of the excess violet radiation from the mercury discharge. I feel that concentration on the red end is not in itself enough.

Many workers, of course, have investigated this problem of improving the colour properties of fluorescent tubes, particularly recently, with the object of mixing them with tungsten but very little work has been done on modifying the tungsten to fit the fluorescent. I have noted with a good deal of interest M. Claude's use of krypton in that way. I think there is a lot more that can be done to make the tungsten lamp fit in with the fluorescent tube.

I am very tempted, of course, to comment on this question of fluorescent colours

in themselves, but I think perhaps on this occasion I should resist that temptation. I will just mention, however, that I have been interested in the opinion of M. Claude that the new American colours are very similar to those which have been established in France. It is an interesting point to me because, as I think you heard earlier in the conference, the question of the international standardisation of fluorescent tubes is coming very much to the fore; I shall be attending a conference very shortly on the subject.

It is always difficult for the standardiser to make up his mind when to standardise and what to standardise. If you do it too soon, you stultify progress; if you do it too late, you find a field of vested interests has grown up and the possibility no longer exists. I would be interested to hear from M. Claude whether he feels that the time is now ripe for standardisation of fluorescent tube colours.

In conclusion, M. Claude, I have three questions. How do you combine the artist and the engineer—do you have two people or do you have one? How do you feel about this question of excess violet radiation from fluorescent tubes? How do you feel about coming to an international agreement on fluorescent tube colours?

DR. J. W. STRANGE: I am afraid I must seek refuge in M. Claude's own statement that tastes and colours should not be discussed. Faced by a paper of this sort, I feel I am very much the layman of the technical type.

I would, however, make one statement of approval of his general feeling in favour of pastel colours of lamps for decorative lighting purposes, but I question whether his principle of general unanimous approval as the main criterion is effective in the world we know to-day. The plain fact is that the great majority of the public is not interested in the same type of effect as the artist or in the type of installation that he has shown to-day. My general impression is that the general public likes the blatant and great splashes of colour, and artistic effects are very often wasted on them.

This was particularly apparent at one of our biggest exhibitions after the war, the one at Battersea, when I was shocked and horrified to find natural foliage illuminated by mercury and sodium lamps—horrible splashes of distorting colour without any artistic value.

One need only walk through the streets of any town to see the use of, say, fluorescent tubes in shop windows. The more obvious the tubes are, the more lines of light one can see, the more the public and the shopkeeper, apparently, appreciate it, so I think public taste in this matter is very often low and not a very helpful guide.

I think the same thing may apply to the question of tube colours, although in France they seem to have an excellent preference for what we will call the de-luxe colours. Taking the world as a whole, I think that the general principle of spontaneous approval does not in fact operate.

I believe it was one of the American journals which recently made an analysis of the preferences, at least in the American market, for the different colours. Those of the high fidelity type similar to those which we have seen to-day represented probably less than 10 per cent. of the total sales, and I think that is probably the same in this country. The de-luxe, or the high fidelity colours like "Natural," represent a relatively small proportion of the total.

It is very interesting to observe the trends of colour in the world as a whole. "White" was, I think, by far the most popular up to a few years ago. Now "Daylight" in the standard form is creeping up and is now the most popular, but both of those are the types which M. Claude has indicated as lacking in the essential requirements for good lighting, so from the point of view of the manufacturer or technical man that principle of spontaneous approval does not operate. Although it fails to operate on colour distribution it may still operate on colour. The public is fairly well

informed on the colours it likes, but the question of whether "de-luxe" or "standard" is beyond the average user and he usually takes what he is told.

Turning to more technical matters, there are one or two points I would like to raise. I was very interested in M. Claude's description of the krypton lamp because I think it is fair to say that in this country, apart from the miners' lamps, it has not been extensively used. In fact, the increasing use of krypton has come about, if at all, from the use of rare gases in quite another field—the field of argon welding. The fact that 99 per cent. of all the argon used is not used in lamps but in welding has brought the price of krypton down greatly and increased its use in this country. I would like to know from M. Claude whether his considerable use of krypton is connected with its use in lamps or whether it is a subsidiary feature of a development of argon welding in France.

I would also be interested to know what he finds, in fact, is the increased efficiency with the type of lamps he has used in these circuits; I imagine it is of the order of 15 or 10 per cent., but I must confess that I am a little ignorant of the exact amount that is to be gained.

DR. H. H. BALLIN: Arising out of the last question on krypton, I am a little surprised to read that the system of tungsten ballast control, according to M. Claude, can only be of value commercially when krypton-filled tungsten lamps are used. I would like to have M. Claude's further advice on this point because I cannot see, with a 50 per cent. increase in list price, how a commercial case can be made out for such a control compared with the conventional system of inductive control gear. I am referring to commercial installations and not domestic installations where the question of first cost is so important and current consumption of less interest.

I note in this country and also, as M. Claude comments, in France, a growing tendency to combine tungsten lighting with fluorescent tubes. It is interesting to see from the slides that in practically all the cases shown the tungsten lamps were separated from the fluorescent installation: they appeared as spot lamps and such like in separate compartments or separate fittings and the fluorescent lighting was on its own. On the other hand, in the sketches shown we have a number of fittings in which tungsten and fluorescent tubes were combined. I would like to know which system, by and large, he considers preferable. In particular, I was interested in Fig. 2, where he shows krypton-filled tungsten lamps giving indirect lighting, whereas fluorescent tubes are producing the direct lighting. As far as I can see, the effect of this is negligible. The amount of indirect lighting that would reach the working plane would be so small that, to all intents and purposes, one would consider the lighting wasted. I would like to know whether the slight colour correction normally possible with a system of mixed lighting can be achieved with a lighting fitting of this kind.

MR. S. S. BEGGS: I would like to ask M. Claude a question about the unanimity in the choice of colours in fluorescent lamps, because in England we have found it very difficult to get any sort of agreement. I gather from the paper and from his presentations that the colours he has mentioned do obtain general favour. Here, we have tried to get some idea of public taste by getting general opinions and carrying out tests, and the tests gave no understandable results. Some people would like one thing, then another, and in a third test they would reverse their decisions completely. I would like to know how he has assessed public opinion; I gather from the paper that it was largely by comment. I think that perhaps the answer is that judgment was mainly of the decorative effect. Particularly, he mentions the "Salon de l'Automobile" and I think that may be the clue: in looking at the decorative effect, one might not be so critical about colour rendering.

Another small point: I am sure that many of us here in England would like to

see better control of fluorescent advertising signs. I believe I am right in saying that the authorities have now taken steps to remove signs from Trafalgar Square and try to restore its dignity. I was very impressed with the slides M. Claude showed and I would like to ask whether in France they have greater control over the number and type of signs, their positions, and so on.

Finally, we all know that M. Claude is a good engineer. I think he is also obviously an artist. I was very impressed with his choice of words. He did not talk of daylight and artificial windows but "shafts of sunlight" and "splashes of colour." I was interested that he thought the artist and the engineer would have to be separate people, because about a year ago I gave that as my own opinion. I did not see how they could be combined and I was interested to hear him give that opinion, too, more especially as I was thinking at that time of the English-speaking peoples in whom you do not get that combination of personalities; I was not thinking of the French, who have an advantage in that they are good engineers and have a particularly good artistic strain. I now find myself in a difficulty, as I must disagree with him when he said that he thinks these must always be two people. I must now make one exception: M. Claude himself.

MR. J. A. WHITTAKER: I feel we should bow our heads in shame. We have invited M. Claude to come here to address us and he has chosen for his subject "The Decorative Approach to Commercial Lighting" and we have spent all this time discussing technicalities. I hope M. Claude will be pleased if the discussion is drawn a little more to the decorative side, which I think must be very close to his heart.

I only want to make two very simple points and I can summarise them, perhaps, by the phrases—persistence of style and the use of an object of interest in the decorative scheme.

With regard to the second point, I would refer to a number of examples in the wonderful slides we have seen where a pendant has been used, I think we might say, as an artistic foil to a rather simple style of built-in lighting which latter fulfils the lighting function technically, and has a pleasing and simple appearance but in which the whole scheme is animated by the decorative pendant. Perhaps M. Claude would say a few more words about such use, which is also quite popular here.

Returning to my first point regarding persistence in style, we can see in this hall, as in many municipal buildings throughout the country, surviving remnants of a style which can be described as "Victorian pseudo-Gothic," in this case brought pleasantly up to date by the insertion of a proscenium arch and balcony in the "Coronation contemporary" manner with matching decoration. In lighting fittings a further style is often introduced, as here, by the use of panelled multi-lamp fittings, which may be classified as of the pre-war "modern" era. I have been very impressed by a persistence as shown by some of the slides this morning of this style adapted for use with fluorescent light sources; it would appear to have remained in favour longer on the Continent than in England in post-war years.

I hope that M. Claude will leave us with the impression that perhaps some day Paris may need to admit us as friendly challengers in the world of aesthetics.

M. CLAUDE (in reply): It is, perhaps, useful to recall that I did not choose the subject dealt with to-day; it was suggested to me by your Papers Committee and I readily agreed to it, in spite of the risks entailed—as evidenced by your questions—because it covers matters that are of deep interest to me.

My paper is, of course, only an essay limited to facts well known to me, i.e., those mostly related to France and to my company's activities.

I must say, in answer to Mr. Penny and Mr. Beggs, that the artist-engineer team is of basic importance. In practice, our estimating department is composed solely of

illuminating engineers who co-operate in all cases with an architect, the architect being chosen by the customer or suggested to him by us. The co-existence of artistic and technical faculties in one and the same individual does not appear to be desirable. The former is composed of imagination and intuition, whilst the latter is tied to scientific principles. The necessary co-ordination of these two points of view, to arrive at the desired result, will only be effective if these functions are kept apart. It is impossible, for instance, to imagine legal proceedings in which a barrister, however capable, could at the same time act as counsel for the prosecution and for the defence.

However, an understanding must be reached between them; the engineer must admit the existence of aesthetic problems and the architect must acquire a modicum of technical lighting knowledge, hence the necessity for educating both. This education has been seriously undertaken and has already reached an advanced stage in France.

The principle of universality that I have put before you is disputed by Dr. Strange and Mr. Beggs. They say that what may be suitable in France is not suitable for you or for Americans. How, then, does one explain the spontaneous rejection, in all countries, of fluorescent lighting for domestic purposes? My principle gives the answer. Women everywhere, who have perhaps more discernment than men and who, in any case and whatever their station in life, are concerned in themselves and for their homes with good taste and susceptibility towards things "pleasing to the eye," immediately rejected the so-called white fluorescent lamps on aesthetic grounds.

It has also been objected—and I understand that it is Dr. Strange's opinion—that, in a general way, the public is not very responsive to artistic lighting effects but prefers the blatant and is perfectly satisfied with several rows of bare tubes in a show-case. I should like to reply fully to Dr. Strange's objection because I find it extremely interesting.

I agree entirely with Dr. Strange that the more the show-cases are lighted, the more dazzling the effect produced, the greater will be the number of people who will crowd in front of it. But I do not agree with his interpretation of the public's taste. If it crowds before show-cases whose dazzling effect offends the taste and conceptions of the good illuminating engineer, is it because it is attracted by vulgar artistic sensations? There is a worse example. We have all seen, in itinerant fairs everywhere, merry-go-rounds and booths all "adorned" with acetylene flares or bare tungsten lamps, the glare and multiplicity being far worse than one gets with the fluorescent lamps in Dr. Strange's show-case. Do the fairground people use this light to woo the favour of the vulgar taste of the public?

I hold, on the contrary, that it is a manifestation—rather crude, of course—of an aesthetic lighting quality effect. It fits exactly into the section where I dealt with "coloured spots." The merchant's show-case, as with the merry-go-round, must be situated in the midst of the boundless night.

These brilliant spots constitute a sort of aesthetic lighting demonstration. If the method is not perfect it is our and not the public's fault, as we have the means to improve it. To cultivate the public's taste is, in fact and as I have said, what M. Andre Granet has been doing for 40 years at the Grand Palais, for the annual Salon de l'Automobile. By constant improvement, the inspiration of his art and his mastery of luminous sources, M. Granet has never failed to interest and attract the crowds of visitors.

This makes me think that everyone reacts to lighting demonstrations and has done so from earliest times. It is an essential duty of the artist, using all known means of expressing himself, to cultivate this feeling and to impart his art to the public. I look upon the lighting art as a criterion of the state of advancement of civilisation.

It is in the same vein that I answer Mr. Beggs's question regarding luminous signs and advertising regulations in France. These are undoubtedly much stricter than in Great Britain; they are, in fact, tyrranical and carry things to the extreme. This

matter was treated in a spirit of good-will and equity before the war, but the Administration now seems to cling to a draconian decree made during the German occupation, the black-out and other conditions that you can well imagine. In short, I am in agreement with the Administration's desire to safeguard genuine historical Paris sites and when it seeks, in other parts of the city, to prevent ugliness. I am against it when it refuses to allow everything unreservedly. Luminous signs and advertisements can be artistic and they have their proper place in the modern city.

The unsatisfactory nature of the effect produced by fluorescent tubes, from the aesthetic standpoint, has impressed me from the earliest days of fluorescent lighting in France, and as far back as 1934 I suggested the addition of neon tubes to the fluorescent sources, which gave very good colour correction. I believe that this idea of adding neon to fluorescent tube emission to obtain satisfactory aesthetic effects has also been followed in your country by at least one manufacturer. It is from this point of view that one must consider the introduction of krypton-filled tungsten lamps, acting as light quality modifiers in place of neon tubes.

In reply to Mr. Penny, regarding the troublesome radiation of fluorescent tubes in the violet region, it seems to me that the most suitable combination from the aesthetic standpoint is that which blends krypton-filled lamps with "Blanc Z" colour fluorescent tubes.

As to the standardisation of fluorescent tube colours, I have already taken a very firm stand in France. Standardisation is essential, both from the national and international viewpoint. The main object is to serve the public. The multiplicity of types produced cannot be tolerated internally, and is senseless from an international aspect at a time when everyone is trying to improve international trading. It would be wise, in my opinion, to select three colours identified with or approaching our colours "Daylight," "Blanc Z" and "Rose de France." I have selected these colours for their spectral quality and not for their luminous efficiency. On the other hand, manufacturers should be given a free hand to produce one or two different colours so as to keep the way open to development. Study and inspection might be undertaken periodically on the international plane.

Dr. Ballin is quite correct when he points out that in all the installations shown on the screen the krypton and fluorescent circuits are separate. The direct association in the same circuit of which I have spoken, *viz.* krypton-filled lamps stabilising fluorescent tubes, has not yet been commercialised in France and will only come on to the market next September. Before marketing a new idea, especially one affecting the aesthetic point of view, we always follow our laboratory studies with a few field trials, either in the company's premises or in the premises of clients well known to us, where we can check results closely. These field trials are always made on a large scale and in this particular case have been carried out with thousands of fittings.

I think this answers Mr. Beggs's query as to our methods of sounding the public. In practice, when working in this way, I have never found any disagreement in the opinions expressed. I know of installations that have been thrown out by clients dissatisfied with the colour rendering of lighted objects; such cases are common in the food trade. Having suggested the use of our "Rose de France" tubes to replace the fluorescent tubes originally supplied, I have not had a single failure; after a trial the client is, in every case, satisfied with the new colour. It is because we are now completely assured of the satisfaction of architects, our clients and our client's customers with the krypton-fluorescence combination that we have decided to launch it commercially.

The different mounting combinations I have shown in the diagrams have been given to indicate the variety of possible combinations that the engineer will be able to suggest to the artist, whose choice will be governed by aesthetic considerations only. I have deliberately included Fig. 2, which has been questioned by Dr. Ballin, because it offends against the lighting engineer's purely technical conceptions. I wanted to

attack technical doctrines, to assert the fact that the very pleasing artistic effect obtained outweighs utilitarian technical lighting concepts.

I want to make it clear that the technical solution I have propounded and that we are going to use in France, besides its aesthetic side, rests basically on our "D.M.S." circuit, which ensures the immediate starting of fluorescent tubes without the use of starter switch or over-voltage. This circuit, which incorporates a magnetic ballast, has been used in France for many years with increasing success. The substitution of the tungsten lamp for the magnetic ballast has the further advantage of having appreciably reduced the first cost of the installation.

Now, why should we use krypton-filled lamps instead of the usual argon-filled ones? Firstly, I do not think it is a commercial proposition to use argon-filled lamps because, with the series arrangement, the tungsten lamp is very susceptible to voltage variation. In practice, the life would be of the order of 600 to 700 hours, which is unacceptable as it would lead to such a high maintenance cost. Naturally this same objection could be levelled against krypton-filled lamps made to the same standard 1,000 hours life, but this is not what I have in mind. I propose to use krypton-filled lamps that are designed to an adjusted luminous efficiency and so to get a considerable increase in lamp life. Instead of the 50 per cent. increase in list price referred to by Dr. Ballin there is, in effect, an actual increase in life to a figure that is of the order of 250 to 400 per cent. The economic aspect is therefore in the client's favour.

With regard to the extraction of the rare gases krypton and xenon which are present only to the extent of one part in a million and one part in ten million in the atmosphere, this has no connection with the actual development or argon production for welding purposes; krypton and xenon remain, therefore, by-products of oxygen production. Our new lighting technique has been built up with our present method of krypton and xenon extraction. A simplified process has been evolved which does not entail the liquefaction of all the air, but involves the washing of considerable quantities of processed air—several cubic metres per second—by small quantities of liquid oxygen, which dissolves the krypton and xenon. There are, therefore, no limits to the supply of krypton and xenon, which can be extracted from the atmosphere in sufficient quantities to meet our manufacturing requirements. With regard to the cost, it is basically a question of the kilowatt-hours required to compress the air and the charges for plant depreciation.

I have been very interested by Mr. Whittaker's remarks regarding style. His comments are quite relevant and recall to me a very instructive incident in which I was involved. A very important French company decided to modernise all the lighting in its head offices. The architects' scheme, using indirect fluorescent lighting had been adopted. The lighting obeyed all the rules of the lighting engineer but, to the great disappointment of the client and architect, it was flat and dull. The client thought regretfully of the good, old installation, the tungsten lamps, their reflectors and lamp-shades. The architect brought his troubles and worries to me and I suggested the addition, in suitable architectural spots, of bracket lamps or bronze and glass chandeliers, porcelain candles and flame lamps—with krypton filling of course. A miracle happened, the lighting effect is very pleasing and the clients have never believed that the fluorescent installation has not been modified.

I want to say in conclusion that, however attached I may be to scientific rules and procedure, if I have to judge between engineering and art, my verdict will be in favour of the good artist.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members:—

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